Brookhaven National Laboratory
Brookhaven Science Associates
CAD Department

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Title: **Statement of Work for the Fabrication of the EBIS Superconducting Solenoid Magnet System**

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- Cognizant Engineer: _____ _____
  L. Snydstrup Date
- Subsystem Manager: _____ _____
  E. Beebe Date
- Project Manager: _____ _____
  J. Alessi Date
- Chief M.E.: _____ _____
  J. Tuozzolo Date
- Quality Assurance _____ _____
  D. Passarello Date

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Statement of Work for the Fabrication of the EBIS Superconducting Solenoid Magnet System

1.0 General.

1.1 Summary

This Statement of Work outlines the steps necessary to engineer, design, manufacture, deliver and set up a superconducting solenoid magnet system at BNL to be used in the Collider Accelerator Department (CAD) Electron Beam Ion Source (EBIS). The system shall be a complete turnkey magnet system. The magnet shall be a 6 Tesla, 2 meter long horizontal solenoid with 204 mm warm bore. The Vendor shall provide a ready-to-operate magnet system complete with integrated power supply, quench protection, alarm and warning system, control hardware and software, and all mechanical and cryogenic equipment necessary for the magnet to meet the specifications.

1.2 Scope

This statement of work outlines the minimum requirements governing the manufacture of the EBIS Superconducting Solenoid Magnet System. It should be read in conjunction with specification CAD-1172, "Specification for EBIS Superconducting Solenoid Magnet System."

The Seller shall:

1. Conduct engineering analyses to determine the parameters needed to design a magnet system that meets the specification and statement of work.
2. Completely design the magnet system.
3. Participate in a presentation of the magnet design to the BNL Cryogenic Safety Review Committee.
4. Manufacture the magnet system.
5. Factory test the magnet system.
6. Deliver the magnet system to BNL.
7. Install and set up the magnet system at BNL.
8. Operate the magnet system and perform acceptance testing.
9. Train BNL personnel to operate the magnet system.

1.3 Access

Designated representatives of the Buyer shall be allowed access to the production and test areas of the Seller's facilities, and, if applicable, the Seller's subcontractor facilities during the progress of work called for by this statement of work. The Seller shall assist and facilitate inspection visits of the Buyer.

2.0 Documents and Standards.

2.1 The following documents are an integral part of the statement of work:

2.1.1 Specification CAD-1172, "Specification for EBIS Superconducting Solenoid Magnet System."

2.1.2 BNL-QA-101, "BNL Seller Quality Assurance Requirements."

2.2 Conflicts

In the event of a conflict between the Technical Specification and this Statement of Work, the Seller shall immediately notify the Buyer. The Buyer in each instance shall determine which document takes precedence and advise the Seller accordingly. Failure of the Seller to so notify the Buyer in any given instance shall not relieve the Seller of the obligation to comply with the Buyer's determination of precedence at no additional cost to the Buyer.

2.3 Revisions

Any specification and/or SOW revisions shall be documented and negotiated by both parties. Any cost differential shall be recorded and approved in writing by both parties.

3.0 Submissions and Approvals.

3.1 Production Schedule.

Following the placement of an order, the Seller shall submit to the Buyer the production schedule showing task duration and milestone completion dates for the following:

1. Conceptual design drawings.
2. Conceptual design review.
3. Detail design drawings.
4. Detailed design/safety review.
5. Delivery of superconductor.
6. Coil winding and tests.

7. Magnet pressure vessels construction.
8. Magnet assembly complete.
9. Power supply, controls, and instrumentation system.
10. Test procedure
11. Factory test.
12. Delivery of magnet system to BNL.
13. Completion of acceptance tests/training at BNL.

All milestone dates shall be the actual dates task completion is expected. This production schedule MUST be submitted to the Buyer within THIRTY DAYS AFTER RECEIPT OF ORDER.

3.2 Manufacturing Plan.

A manufacturing plan with major event milestones shall be included in the response to the RFQ. The manufacturing plan shall identify parts and subassemblies, showing integrated flow into the end item. This plan shall be sufficiently detailed in nature to show the flow of the construction and to understand the manufacturing processes being used. It shall include critical manufacturing operations and inspection/test checkpoints.

3.3 Design Review Documentation (See 4.0).

Five copies of the presentation material used by the Seller shall be provided to the technical contact for the contract at least 10 days prior to the conceptual design review and detail design/safety review dates.

3.4 Test Procedure.

See BNL-QA-101, paragraph 4.6. The test procedure shall be submitted 6 weeks prior to the performance of the tests and it shall include, but not be limited to, the following parts:

3.4.1 Start up time. Record helium consumption.
3.4.2 Full field quench with full dewar.
3.4.3 Quench recovery time.
3.4.4 Axial load capacity.
3.4.5 Field decay rate.
3.4.6 Field ramp time.
3.4.7 Set point adjustment.
3.4.8 Set point drift.
3.4.9 The helium evaporation rate shall be demonstrated at 6 Tesla field for three cases: persistent mode and current leads both installed and removed, and powered by power supply (leads installed). Helium rates shall be measured while helium level is at or near full. For LN2 cooled heat shields, the helium rate shall be measured with LN2 level at 50% and at full.

3.4.10 LN2 evaporation rate (if LN2 cooled shield is used).

3.4.11 Helium filling time (while cold and operating in persistent mode).

3.4.12 Field mapping from magnet center to 400 gauss field points, each direction.

Bz: Measure from z = 0 to +/-500mm at steps of delta z = 30mm; and from z = +/-500mm to 400 gauss at steps of delta z = 15mm. Five such measurements should be made for: r = 0 mm; r = 5 mm, theta = 0 and 90 deg; r = 10 mm, theta = 0 and 90 deg.

Br: Measure at r = 10mm, from z = 0 to 400 gauss field points (+/-) at steps of delta z = 300mm, eight angular points at each z: θ = 0, 45, 90, 135, 180, 225, 270 degrees.

Field mapping results shall be provided in tabular form and as plots of Bz vs Z, with error bars. Polar plots shall be provided for the Br vs theta maps.

3.4.13 Vacuum Testing. Cryogenic and vacuum vessels shall be leak tested with a helium mass spectrometer which has a minimum sensitivity of 2×10^{-10} atm-cc/sec. The leak rate shall be less than 2×10^{-10} atm-cc/sec with the chamber internally under a vacuum of less than 1×10^{-5} torr and externally pressurized to 1 atmosphere minimum.

3.5 Upon completion of all aspects of construction and testing, the Seller shall submit to the Buyer:

a) Five (5) complete sets of ‘as built’ drawings of all parts, assemblies and schematics of the system.
b) Five (5) copies of engineering analyses. These may be the same documents submitted for the detail design review, but updated with latest revisions.
c) An electronic copy (in DWG or DXF format or an approved equivalent) of the ‘as-built’ drawings. A 3D top assembly drawing of the magnet system shall be provided in IGES, ProE, or AutoCAD Desktop or Inventor format. A 3D simplified representation or ‘shrinkwrap’ of the envelope is preferred.
d) Five (5) copies of the manuals for system operation and component servicing.
e) Five copies (5) of the final test report, verifying conformance to the requirements of the specification. The final test report must be approved prior to shipment of the magnet system. Review and approval of the test report will be provided by BNL within 10 days of receipt.

4.0 Design Reviews.

The following design reviews are required:

4.1 Conceptual Design Review

The conceptual design review shall take place at the Seller's facility. The conceptual design presented shall include sufficient detail that shows that the requirements of the design specification are met. Layout assembly drawings and sections of the solenoid magnet, specifications for power supply, control, and instrumentation, and critical calculations shall be included in conceptual design package. A calculation of the maximum axial magnetic load due to the magnetic shim shall be required.

4.2 Detailed Design/Safety Review

This review shall take place at BNL. The Seller will present the final magnet system configuration and cryogenic system design for technical review and safety evaluation by the Cryogenic Safety Committee. This presentation will be both an oral and written report which will include detailed drawings and the full quench, structural and cryogenic analyses described in 7.0.

5.0 Tooling and Fixture Design

It is the responsibility of the Seller to design all tooling and fixtures for the handling, assembly, disassembly and maintenance of the magnet system assemblies and subassemblies. Tooling and fixture design and fabrication should be consistent with the production schedule.

6.0 Material Procurement/Certifications

The procurement of all materials used for the fabrication and packaging of the magnet system is the responsibility of the Seller. Material certification is required for all materials used in the coil assemblies and magnet vessels. The timely acquisition and use of materials with a finite 'shelf life' is mandatory.

7.0 Engineering Analyses

7.1 As part of the Seller's detailed design, the following engineering analyses must be completed and the results made part of the detailed design report.

a) Structural analysis.
b) Cryogenic analysis.
c) Quench protection analysis.

The Buyer requires a formal, written submission of these analyses, and, in the event that parameters change after these analyses are initially completed, submissions must be made for the final parameter set.

7.2 Relief Valve Calculations. As part of the cryogenic analysis, safety-related calculations shall include, but not be limited to, relief device sizing for the following potential conditions:

a) Loss of vacuum
b) Magnet quench
c) Failure and leakage of cryogenic vessels, helium and nitrogen.

Relief valve sizing calculations should be in accordance with or equal to ASME Code, Section VIII, Division 1, Appendix 11. Restrictions in the flow path should be accounted for.

8.0 Construction Requirements

8.1 Fabrication Environment

The coil(s) shall be fabricated in an environment free of metallic particles, dirt, and welding or chemical fumes. The coil and all materials used in its construction shall be protected from dirt, moisture, and damage during fabrication, handling, and storage. The insulation material shall be handled with clean gloves and all measures taken to prevent contamination with water, oil, solvent, dirt, metal chips, or other foreign matter. One metal chip can destroy a coil or lead to premature failure, so winding in a protected area as described above is mandatory.

8.2 Welding

The welding used in the magnet construction shall be performed by qualified operators working to ASME Boiler and Pressure Vessel Code standards.

8.3 Pressure and Vacuum Vessels

The pressure and vacuum vessels and associated hardware shall be designed using design principles embodied in the ASME Boiler and Pressure Vessel Code Section VIII. An ASME Code stamp is not required.

9.0 Safety

Prior to the installation of cryogenic equipment at Brookhaven, a safety review by the BNL Cryogenic Safety Committee will be conducted so that any safety issues may be identified and resolved. The Vendor shall participate in the review to provide an explanation of the cryogenic analyses and assumptions relevant to safe cryogenic design.

10. Testing and Inspections

10.1 ‘In Process’ Testing and Inspections

An inspection and testing schedule shall be included in the manufacturing plan with the inspections coinciding, in general, with important milestones, e.g. high potting of the coil, etc. Witnessing of manufacturing milestones may be conducted at the discretion of BNL. Reasonable notice of 10 days by the Seller to BNL is required. In addition, the Buyer reserves the right to inspect the progress on demand with reasonable notice given.

10.2 Factory Testing

Prior to shipment to BNL, the completed magnet system will be tested at the manufacturing site in accordance with the test procedure. All performance criteria will be demonstrated and recorded. BNL shall be provided 3 weeks notice prior to the factory test to witness a subset of this testing.

10.3 General Acceptance Testing

Upon delivery, the Seller will direct and participate in the assembly and operation of the magnet system. The magnet system will be operated and tested to verify conformance with the operational and design parameters. When the magnet has met the performance specification to the satisfaction of both the Buyer and the Seller, acceptance will be made. Assembly and acceptance testing shall take place within one (1) month of delivery.

11.0 Rework and Repairs

The following definitions apply:

Repair: Restoration of an item to an acceptable condition through approved repair procedures (e.g. welding, splicing, etc.).

Rework: The completion or correction of an item to a conforming condition by processing the material through conventional operations which are part of the normal manufacturing process.

If failure of the magnet system or any components occurs during or after fabrication that requires repair or changes to the conceptual/detail design, the fabrication shall stop and the Buyer shall be immediately notified. The Buyer at his discretion shall ask for retesting, additional review, or proposals for repair, if possible.

Proposals for repair shall include adequate means for evaluating the repair and for the absence of damage to the existing work. No proposed repair shall be initiated without approval of the Buyer. No repair shall be considered successfully accomplished without inspection and approval by the Buyer.

All repairs shall be at the expense of the Seller.

Notification of rework is not required.

12.0 Delivery

Delivery shall be made at Brookhaven National Laboratory, Upton, Long Island, New York, on or before the contract delivery date. The Vendor shall coordinate delivery with CAD personnel.

13.0 Shipping

Seller shall design and fabricate protective packaging with adequate performance to ensure protection against excessive environments occurring during handling and shipment. System components shall be blocked, braced, and protected from damage. Radial and axial polymer blocks are recommended. Two sets of recording accelerometers for three directions of motion shall be firmly attached to each susceptible truck package. The packaging shall include lifting eyes suitable for lifting the system skid from above, as well as provisions for lifting with a fork truck. All pressure vessel openings shall be sealed. The Seller shall be responsible for procuring all permits, etc., necessary for the delivery of the magnet system to the Buyer's facilities.

14. Quality Assurance

The Quality Assurance requirements are as stated in Specification CAD-1172.

15. Fixtures

Handling and assembly fixtures paid for by the Buyer shall be shipped along with magnet system at the Buyer's option.